GENETICS

Comparison of the Performance of 1966- Versus 2003-Type Turkeys When Fed Representative 1966 and 2003 Turkey Diets: Growth Rate, Livability, and Feed Conversion¹

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ABSTRACT Body weight, livability, and feed conversion of a randombred control turkey line (RBC2) started in 1966 at The Ohio State University was compared with that of modern commercial turkeys hatched in 2003 when fed representative 1966- and 2003-type diets from hatch (March 5, 2003) through 196 d of age. Each pen of modern turkeys consisted of 5 birds each of the Nicholas, British United Turkeys of America, and Hybrid strains. Eight groups (i.e., 2 strains (RBC2 vs. modern), 2 sexes, and 2 dietary regimens) were randomly assigned into each of 4 blocks of 8 litter floor pens (32 total) for growout. Using the BW performance of the 2 strains on the modern feed as the basis, the study showed that the 2003 turkeys were approximately twice as heavy as the 1966 RBC2 at the 4 slaughter ages and that tom weights have increased by 186, 208, 227, and 241 g/yr, and hen weights have increased by 164, 179, 186, and 205 g/yr at 112, 140, 168, and 196 d of age, respectively, over the past 37 yr. Cumulative feed conversion (kg of feed/kg of BW) was approximately 20% better in the 2003 tom turkey on the 2003 feed (2.638) than in the RBC2 tom on the 1966 feed (3.278) at 20 wk of age. Feed efficiency to 11 kg of BW in the 2003 toms (2.132 at 98 d of age) was approximately 50% better than in the RBC2 toms (4.208 at 196 d of age). The number of days to reach that weight was halved during this period of time. Growth performance during the different periods of the study appeared to be strongly affected by type of feed used and seasonal changes in ambient temperature. Overall livability was very good for all groups, but the mortality level of the RBC2 was consistently higher, although not significantly so, than for the modern birds.

Key words: turkey, body weight, feed conversion, livability, genetic change

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INTRODUCTION

Selection pressure applied by industry geneticists has greatly increased growth rate, reduced feed conversion, decreased age to slaughter, and has increased the yield of edible meat for commercial turkeys. Genetic changes, along with changes in performance brought about by improvements in management, housing, nutrition, and disease prevention, combined with the efficiencies of vertical integration, have contributed greatly to the increase in per capita consumption of turkey meat, which has risen from about 1 kg in 1950 to about 7.9 kg in the United States in 2004 (USDA, 2005).

In the late 1950s, poultry geneticists had the foresight to develop random breeding populations of broilers and turkeys using crosses of several current commercial and research strains as their base. McCartney (1964) reported the development of the first randombred turkey strain that was developed at the Ohio Agricultural Research and Development Center (OARDC; Wooster, OH) in 1957. That strain has become known as the RBC1 and is still maintained at the OARDC. A second randombred turkey strain (now known as the RBC2) was initiated in 1966 by Nestor (Nestor et al., 1969), and it was developed using 2 of the most popular commercial strains in 1966. It also continues to be maintained at the OARDC. Those randombred turkey strains, like their broiler counterparts, are extremely valuable for measuring genetic change in various performance traits of turkey populations over time. Several different experiments have been reported using randombred broilers to estimate genetic change of commercial stocks (Marks, 1971; Chambers et al., 1981; Qureshi and Havenstein, 1994; Sherwood, 1977; Cheema et al., 2003: Havenstein et al., 1994a,b, 2003a,b), but none other than 2 preliminary reports from the current study (Havenstein et al., 2004 a,b) have been reported using randombred turkeys to measure changes in commercial turkey performance over time.

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Item	T03-1	T03-2	T03-3	T03-4	T03-5	T03-6	T03-7	T03-8
Weeks fed for toms	1 to 2	3 to 4	5 to 6	7 to 8	9 to 10	11 to 13	14 to 16	17+
Approximate amount fed, kg/tom	0.4	1.0	2.0	3.5	5.0	6.0	7.0	Market
Weeks fed for hens	1 to 2	3 to 4	5 to 6	7 to 8	9 to 10	11 to 13	14 to 16	1 <i>7</i> +
Approximate amount fed, kg/hen	0.3	0.8	12.0	1.8	2.5	3.7	5.0	Market
Feed form	Crumbles	Crumbles	Pellet	Pellet	Pellet	Pellet	Pellet	Pellet
Calculated analysis								
ME, kcal/kg	2,950	2,950	3,000	3,100	3,250	3,350	3,400	3,550
CP, %	27.5	26.5	25.5	23.5	21.5	20.0	18.0	14.5
Lys, %	1.80	1.70	1.65	1.45	1.35	1.20	1.05	0.85
Met + Cys, %	1.20	1.15	1.10	1.00	0.95	0.90	0.80	0.60
Thr, %	1.15	1.10	1.00	0.90	0.80	0.70	0.60	0.50
Ca, %	1.45	1.40	1.30	1.20	1.15	1.10	1.00	0.85
Nonphytate P, %	0.85	0.80	0.75	0.70	0.65	0.60	0.55	0.45

The objective of the current study was to compare the relative performance of the RBC2 vs. composite pens of 3 modern primary turkey breeds placed during 2003 when they were grown on dietary regimens that were representative of what was being fed to commercial turkeys in 1966 and 2003. The study was designed to measure the relative contribution of genetics and nutritional management to the changes in production and processing traits, both edible and inedible, during the 37-yr period from 1966 to 2003. Growth, feed efficiency, and livability of the progeny turkeys used in the present study are given here.

MATERIALS AND METHODS

Strains and Strain Management

In early 2003, a study using the RBC2 randombred control turkey line from the OARDC was utilized to compare its performance with that of the commercial turkey strains available in early 2003, when fed representative 1966 and 2003 dietary regimens. The BW, feed consumption (FC), and cumulative mortality were measured at 2-wk intervals from 112 to 196 d of age.

The study consisted of a $2 \times 2 \times 2$ factorial arrangement of treatments with 4 replicate blocks of 8 treatment pens. With the exception of FC and livability, which were collected and analyzed on a pen basis, all other data were collected and summarized on an individual bird basis. That is, the overall factorial experiment consisted of 2 strains (RBC2 vs. modern), 2 sexes (toms and hens), and 2 dietary regimens that were thought to be representative of what was being fed to turkeys in 1966 and 2003. All treatment pens for the modern strain consisted of a composite of 5 birds each of Nicholas, British United Turkeys of America, and Hybrid turkeys. Poults from the RBC2 strain were hatched and sexed at the OARDC and were then transported by van on the evening of March 5, 2003, to the North Carolina State University Turkey Educational Unit. The Hybrid and British United Turkeys of America poults were hatched, sexed, and delivered by company employees, and Nicholas poults were hatched and sexed by Sleepy Creek Hatchery (Goldsboro, NC) and were then transported by North Carolina State University personnel to the test site early on the day of placement. All poults were then neck-tagged for individual identification and were placed 15 birds/8.55 m² of pen early on the morning following hatch, with the exception that, due to a shortage of poults, the RBC2 female pens received only 14 birds/pen. The test flock was placed into 32 pens within a 40-pen curtain-sided house in a randomized block design using the factorial arrangement described above with 4 replicate blocks of 8 treatment pens. Warmroom brooding was accomplished using 2 propane heaters mounted near the ceiling in each end of the building. The hot air from the heaters was directed into stirring fans aimed at the ceiling that mixed and distributed the warm air evenly into all pens. Each pen was also equipped with an incandescent infrared heat lamp for spot brooding during the first 10 d of age. Each pen also contained 1 bell-type hanging waterer and 1 tube-type hanging feeder. Continuous light was provided for the first 3 d, and 23L:1D was provided thereafter. Brooder temperature was 32°C and was to the degree possible reduced 2.6°C/wk until an ambient temperature of 21°C was reached. Thereafter, the temperature of the facility was maintained as close as possible to an average of 21°C. Due to the time of year that the birds were grown (8 to 28 wk of age during mid-May to mid-September), however, and due to the fact that they were grown in an open curtain-sided house, the ambient temperatures were considerably above 21°C during most of the growout period (Figure 1). Water and feed were supplied for ad libitum consumption. Neck tags were replaced with wing badges at approximately 6 wk of age.

Dietary Regimens Used

The 1966 dietary regimen was based on diets published by Ensminger (1967), who stated that they were representative of diets being fed in 1966. The modern diets were designed by North Carolina State University nutritionists based on current field experience as to the types of diets that were being fed in early 2003. For the 2003 dietary regimen, both starter diets (first 4 wk) were fed as crumbles, and all grower and finisher diets were fed as pellets. All diets for the 1966 dietary regimen were fed as mash, with the starter being fed from 0 to 56 d, the grower from

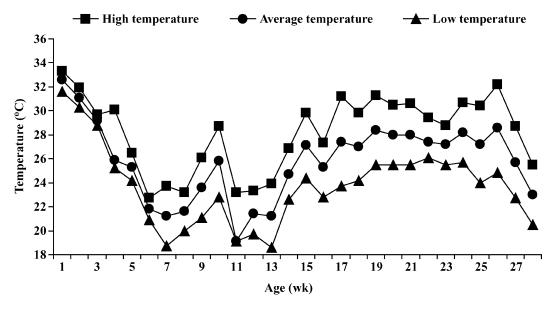


Figure 1. House temperatures by week of age in a 1966 vs. 2003 turkey strain and diet comparison.

57 to 112 d, and the finisher from 113 to 196 d of age. The 2003 starter and grower dietary regimens were fed as 7 different rations by 2-wk periods from hatch to 98 d of age. The 2003 finisher diet was fed from 99 through 196 d of age. Water and feed were supplied for ad libitum consumption. The calculated analyses of the 2 sets of diets are provided in Tables 1 and 2.

Other Experimental Procedures

Individual BW and pen FC were measured at 2-wk intervals from hatch to 112 d of age and at 4-wk intervals from 112 to 196 d of age. Mortalities and the BW of all mortalities were recorded daily on the pen record of the pen in which they occurred. All living birds were individually weighed, and the feed remaining in each pen was weighed back at 14, 28, 42, 56, 70, 84, 112, 140, 168, and 196 d of age for the calculation of FC (kg of feed/kg of BW). The FC was calculated for the individual periods, as well as cumulative over all periods to the age involved for total live plus dead weight.

Table 2. Year 1966 turkey diet formulations¹ and feeding program, with mash fed throughout

Item	T66-1	T66-2	T66-3
Diet	Starter	Grower	Finisher
Weeks of age fed	0 to 8 wk	9 to 16 wk	17 to market
Calculated analysis			
ME, kcal/kg	2,800	2,930	3,000
CP, %	29.0	22.0	17.0
Lys, %	1.72	1.14	0.80
Met + Cys, %	0.92	0.69	0.57
Ca, %	1.47	1.28	1.35
Nonphytate P, %	0.69	0.58	0.77

¹From Ensminger (1967).

Statistical Analysis

The overall design consisted of a $2 \times 2 \times 2$ factorial with 2 strains (RBC2 and modern), 2 sexes, and 2 dietary regimens with 4 replicate blocks of the 8 factorial treatment pens. The data, with the exception of FC and livability, were recorded and analyzed on an individual bird basis. All data were analyzed using the GLM procedure of SAS (SAS Institute, 1996). When possible, the 2- and 3-way interactions of strain, sex, and diet were included in the model for the analysis of all traits measured. At 196 d of age, the first 3 replicate blocks had already been slaughtered, so only 1 pen/treatment was available and therefore only the main effects and 1-way interactions of strain, sex, and diet could be included in the 196-d analysis. No analysis could be performed on the single observation per test group for FC from the last block at 196 d of age. All mortality data were transformed by arc sin before analysis. Mortalities after 112 d were not analyzed due to the first block of cages having been slaughtered for processing at 112 d of age.

RESULTS AND DISCUSSION

Growth Rate

Average BW from several ages measured are summarized in Table 3. For reasons that are not totally clear, the growth rate for all of the turkeys used in the current study was below normal. For example, the RBC2 toms in this study weighed 2.47, 6.29, and 7.85 kg when grown during the late spring and summer, whereas their full sibs produced and grown during the winter and early spring in Wooster, Ohio, weighed 2.87, 7.77, and 9.86 kg at 56, 84, and 140 d of age (K. E. Nestor, personal communication). Likewise, the modern toms weighed

Table 3. Body weight of modern 2003 and 1966 randombred turkeys by strain, diet, sex, and age

									Age (d)					
Item	Diet^1	Sex	Hatch	14	28	42	26	70	84	86	112	140	168	196
Strain ² 2003	1	Male		442	1.211	2.660	4.798	6.620	6379	11.570	13.166	15.540	18.105	19.942
2003		Male		298	782	1,941	3,344	4,910	7,400	9,971	12,246	16.462	20,107	21,386
1966	2003	Male	55.9	303	732	1,487	2,479	3,388	4,633	5,715	6,289	7,853	889'6	11,027
1966		Male		219	505	1,183	1,903	2,640	3,814	5,775	6,397	8,329	10,209	11,143
2003	- '	Female		418	1,084	2,357	4,087	5,624	7,801	9,591	10,807	12,431	13,741	14,978
2003		Female		269	099	1,580	2,701	3,916	5,792	7,487	8,882	11,061	12,538	14,835
1966	- '	Female		269	609	1,205	1,989	2,632	3,518	4,351	4,741	5,805	6,839	7,410
1966		Female		189	409	928	1,496	2,078	2,966	3,817	4,804	6,787	7,251	7,907
Strain and feed average														
2003			68.4	430	1,148	2,509	4,443	6,122	8,590	10,580	11,987	13,986	15,923	17,389
2003			67.4	283	721	1,760	3,022	4,412	6,596	8,729	10,564	13,762	16,923	17,682
1966	2003		55.8	286	029	1,346	2,234	3,010	4,076	5,033	5,515	6,829	8,263	9,218
1966			56.9	204	457	1,055	1,699	2,359	3,390	4,496	5,600	7,258	8,730	9,511
Pooled SEM			8.0	5.2	12.0	25.4	45.6	63.2	88.1	107.5	116.0	167.7	255.5	436.8
Source of variation									<i>P</i> -value					
Block			0.6314	0.0590	0.0371	0.0109	0.0001	0.6116	0.0001	0.0001	0.0001	0.0458	0.0078	NA^3
Diet			0.9089	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.3651	0.0182	0.3489
Sex			0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Strain \times diet			0.0751	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0043	0.8550	0.9983
Strain \times sex			0.0001	0.4617	0.3986	0.0802	0.0005	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
$Sex \times diet$			0.5429	0.9201	0.3489	0.6731	0.2466	0.2716	0.3436	0.1030	0.0016	0.0001	0.0001	0.1318
Strain \times sex \times diet			0.6416	0.3376	0.5515	0.2394	0.9124	0.2869	0.2351	0.0945	0.0038	0.0001	0.0001	0.0318

¹2003 = broiler dietary regimen representative of those being fed in calendar year 2001; 1966 = broiler dietary regimen representative of those being fed in 1966 (adapted from Ensminger, 1967). Both starter diets were fed as crumbles, and finisher diets were fed as 7 to 112 d, and the finisher from 113 to 196 d of age. The 2003 dietary regimen was fed as 7 different rations by 2-wk periods from hatch to 98 d of age. The 2003 finisher diet was fed from 99 through 196 d of age. ²2003 = composite of 5 birds each of Nicholas, British United Turkeys of America, and Hybrid turkey strains; 1966 = RBC2 randombred control strain from The Ohio State University (Wooster). ³NA = not applicable; data from only 1 block of 8 pens available for analysis.

Table 4. Relative BW performance¹ by the age measured of the 4 strainsex groups on the 2003 dietary regimen compared with the performance on the 1966 dietary regimen for the modern 2003 and 1966 randombred turkeys

		Age at	evaluation	of strain-	sex group ²	!
Strain-sex	56 d	98 d	112 d	140 d	168 d	196 d
2003 toms 2003 hens RBC2 toms	+30 +44 +26	+21 +26 +18	+7 +18 -2	-6 +11 -6	-10 +8 -5	-2 -1 -2
RBC2 hens	+25	+18	-1	-14	-2	+6

¹ [(BW on 2003 feed/BW on 1966 feed) 100] – 100.

4.80, 13.17, and 15.54 kg at these same ages, whereas field data from around the world compiled by Ferket (2003) indicates that toms should have weighed about 3.58, 12.32, and 17.00 kg at these ages. Thus, the RBC2 was 15 to 20% lighter in weight than its sib flocks in Ohio, and the modern strain was 7% above and 9% below year 2003 field flocks at 112 and 140 d of age. It is believed that the depression in growth rate was largely due to the fact that North Carolina experienced an extremely hot, humid spring and summer throughout the time when these birds were 70 to 196 d of age. Nevertheless, no signs of disease

were observed at any time during the growing period for this flock, and all of the birds involved were subjected to the same ambient conditions, so the relative performance levels of the 2 types of turkeys should not have been affected.

The RBC2 strain was significantly (P < 0.0001) smaller at hatch by approximately 11.5 g/poult than were the poults of the modern strains (Table 3). As expected, there were no significant differences among the poults that were randomly assigned to the different blocks or to the different feeding programs at the time of hatch. Measurements of BW at the different ages revealed significant block or area of the house effects for most of the ages measured, so those effects were statistically removed in the analyses. Highly significant differences were observed (P < 0.001) between the strains, diets and sexes, and in the strain × diet interaction at all ages measured from 14 through 112 d of age. The same level of significance continued to be observed for strain and sex at the later 3 ages studied (Table 1). Not surprisingly, in light of the large difference in growth rate between these 2 strains, highly significant 2- and 3-way interactions were also observed. If one compares the relative performance utilizing the average for both sexes for the modern strain on the modern feed vs. the old strain on the modern feed,

Table 5. Feed conversion by period of age for modern 2003 and 1966 randombred turkeys when fed representative 1966 and 2003 diets by strain, diet, and sex

							Feed con	version by	period of	age (d)			
Item	Diet ¹	Sex	0 to 14	15 to 28	29 to 42	43 to 56	57 to 70	71 to 84	85 to 98	99 to 112	113 to 140	141 to 168	169 to 196
Strain ²													
2003	2003	Male	1.368	1.552	1.535	1.718	2.360	2.085	3.546	3.702	4.443	4.040	6.050
2003	1966	Male	1.848	1.614	1.640	2.268	2.625	2.691	2.953	3.465	4.046	3.968	9.813
1966	2003	Male	1.349	1.645	1.700	1.942	2.528	2.343	3.102	5.352	4.665	4.161	4.969
1966	1966	Male	1.730	2.716	1.758	2.623	3.056	2.820	2.772	3.494	4.608	5.563	5.796
2003	2003	Female	1.349	1.527	1.509	1.790	2.386	2.257	3.006	4.491	4.411	6.514	8.522
2003	1966	Female	1.681	1.890	1.694	2.163	2.596	2.456	3.470	4.109	3.997	7.300	9.984
1966	2003	Female	1.579	1.711	1.798	2.048	2.744	3.019	3.216	5.412	3.576	4.860	10.966
1966	1966	Female	1.783	3.301	1.895	2.320	2.824	2.847	3.468	3.024	5.065	6.634	9.523
Strain	and feed	l average											
2003	2003	. uveruge	1.358	1.540	1.522	1.754	2.373	2.171	3.276	4.096	4.427	5.277	7.286
2003	1966		1.764	1.752	1.667	2.216	2.610	2.574	3.212	3.787	3.787	5.634	9.898
1966	2003		1.464	1.756	1.749	1.995	2.636	2.681	3.159	5.382	4.120	4.510	7.998
1966	1966		1.756	3.008	1.826	2.472	2.940	2.834	3.120	3.259	4.836	6.098	7.660
Pooled	SEM		0.044	0.146	0.036	0.071	0.145	0.177	0.302	0.391	0.214	0.385	NA^3
0								P-va	lue				
Source	of varia	tion											
Strain			0.1325	0.0001	0.0001	0.0001	0.0079	0.0052	0.9977	0.1342	0.2822	0.6365	NA
Diet			0.0001	0.0001	0.0002	0.0001	0.0142	0.0366	0.4776	0.0001	0.0345	0.0080	NA
Sex			0.4392	0.0382	0.0165	0.2627	0.9639	0.2136	0.6660	0.4639	0.9138	0.0001	NA
	\times diet		0.0809	0.0001	0.1974	0.8832	0.7487	0.3286	0.5931	0.0049	0.0064	0.0485	NA
	× sex		0.0009	0.3399	0.0533	0.4203	0.9735	0.1394	0.1584	0.1503	0.1600	0.0066	NA
Sex ×		11 .	0.0157	0.0578	0.2502	0.0074	0.2306	0.0456	0.1649	0.4365	0.0016	0.3184	NA
Strain	\times sex \times	diet	0.8148	0.6022	0.6872	0.2587	0.3460	0.6339	0.9429	0.8683	0.0612	0.7125	NA

¹2003 = turkey dietary regimen representative of those being fed in calendar year 2003; 1966 = turkey dietary regimen representative of those being fed in 1966 (adapted from Ensminger, 1966). Both starter diets were fed as crumbles, and the 1966 grower diet was also fed as crumbles. All 2003 grower and finisher diets were fed as pellets. For the 1966 diet regimen, the starter was fed from 0 to 56 d, the grower from 57 to 112 d, and the finisher from 113 to 196 d of age. The 2003 regimen was fed as 7 different rations by 14-d periods from hatch to 98 d of age. A finisher diet was fed from 99 through 196 d of age.

 $^{^2}$ Values indicate percentage of performance increases or decreases in birds on the 2003 regimen vs. the 1966 regimen.

²2003 = composite of 5 birds each of Nicholas, British United Turkeys of America, and Hybrid turkeys; 1966 = RBC2 randombred control strain from The Ohio State University (Wooster).

³NA = not applicable; data from only 1 block of 8 pens available.

the modern 2003 strain was approximately twice as heavy (i.e., 2.17, 2.05, 1.93, and 1.89 times) as the 1966 RBC2 at 112, 140, 168, and 196 d of age.

Using the BW performance of the 2 strains on the modern feed as the basis, one can estimate that tom weights have increased by 186, 208, 227, and 241 g/yr, and hens weights have increased by 164, 179, 186, and 205 g/yr at 112, 140, 168, and 196 d of age, respectively, over the past 37 yr. This is somewhat more than what the field data collected and summarized by Ferket (2003) showed, which indicated that tom weights at 126 d of age increased at a rate of 195 g/yr from 1966 to 2003. Market turkey hens are not normally kept to these ages, so comparable field data are not available. The field data from 98 d of age (Ferket, 2003) shows an increase of 65 g/yr for hens, whereas, the 98-d data from this experiment (not shown herein) shows a change of 141 g/yr. It is not clear as to why there is this discrepancy between the results from the 2 sexes herein with the field data.

Contribution of Genetics and Nutrition to Changes in Growth Rate. Sherwood (1977) and Havenstein et al. (1994a, 2003a) reported that about 85 to 90% of the change in commercial broiler performance from 1957 until the years they conducted their comparisons have been due to the genetic selection practiced by commercial breeding companies and that the other 10 to 15% has taken place due to changes in nutritional management. One cannot reach such a clear conclusion from the data reported on turkeys herein. In fact, if one examines the growth rate data in Table 3 and compares the relative performance of the strain-sex groups on the 2003 vs. the 1966 rations, one can see a considerable difference as to how the strains and sexes react to the 2 dietary regimes over the course of the experiment. The calculations in Table 4 are an attempt to demonstrate the relative differences in response to the 2 dietary regimens.

Both sexes of both strains performed much better on the 2003 diets from hatch to 12 wk of age than on the 1966 diets (Tables 3 and 4). Thereafter, with the exception of the modern hens, the birds on the 1966 diets performed better than those on the 2003 diets. As can be seen from Figure 1, after 9 to 10 wk of age, the ambient temperatures started rising, and the birds on the 1966 diet, which contained higher protein and lower energy, started performing better than those on the higher energy and lower protein modern diets. It appeared that the birds consuming the modern high-energy diets reduced their intake as an adaptive measure to minimize their heat stress, and, consequently, the reduced protein intake limited their growth. In contrast, the birds consuming the 1966 diet containing lower energy and higher protein were able to consume more feed during heat stress and therefore more protein and other nutrients to support greater weight gain. Veldkamp et al. (2002) reported that turkeys modulate feed intake when exposed to high ambient temperatures in relation to the caloric density of the diet. Although data to confirm their observation are not available from the present study, this seems to be the most logical explanation for this switch in performance on the 2 diets. Follow-up studies need to be conducted to better understand how to feed market turkeys under high ambient temperatures. From the current study, however, the answer one would give as to whether nutrition and nutritional management has improved performance during the 37-yr period from 1966 to 2003 is clearly dependent upon the flock's age and the ambient temperature under which the birds are grown.

Feed Efficiency

Feed consumption and BW records were collected by 14-d periods from hatch to 112 d of age and then by 28d periods from 112 to 196 d of age. The FC was calculated for each pen by individual period and cumulative overall periods to the age involved. The FC by period of age is summarized by strain, diet, and sex in Table 5. The 2003 turkeys had consistently better FC during the first six 2wk age periods through 84 d of age than did the 1966 RBC2 strain. Once the temperatures began to increase, the FC of both strains increased dramatically, and those birds fed the 1966 diet in most of the comparisons had numerically or significantly better FC than did those on the modern high-calorie diets. The FC was consistently poorer in both strains on the 1966 diets than on the 2003 diets through 84 d of age, but, consistent with the BW data, FC was in most cases (except during the last period when temperatures began to decrease) better on the 1966 diet after that age.

The data in Table 6 provide a summary of the cumulative FC data by strain, sex, and feeding regimen for each age measured. Highly significant differences in FC were observed between the strains and diets at all ages, but not between the sexes. The lack of a significant effect due to sex is probably due to a problem that arose when the poults of one of the modern strains were received from the commercial hatchery. Although the 2 groups were labeled as toms and hens, they turned out to be all toms. This was not realized until the birds had been weighed several times, and it was then decided to leave the pens intact. Because the birds were individually identified, this problem was easily handled for the analysis of the other traits but could not be rectified due to the confounding of having both males and females consuming feed in the modern female pens for FC. So, all pens of modern females were comprised of 10 hens and 5 toms. Thus, the sex effect was undoubtedly less than what it should be

Cumulative FC for the toms (which was not affected by the above sex delivery problem) was approximately 20% better in the 2003 toms on the 2003 feed (2.638 kg of feed/kg of BW) than in the RBC2 toms on the 1966 feed (3.278) at 20 wk of age. Cumulative FC to 11 kg of BW in the 2003 toms (extrapolated to be 2.132 at approximately 98 d of age) was approximately 50% better than in the RBC2 toms (extrapolated to be 4.208 at approximately 196 d of age). Thus, the number of days to reach that BW was halved during this 37-yr period.

Table 6. Cumulative feed conversion of modern 2003 and 1966 randombred turkeys when fed representative 1966 and 2003 diets by strain, diet, sex, and age

								Age (d)					
Item	Diet ¹	Sex	14	28	42	56	70	84	98	112	140	168	196
Strain ²													
2003	2003	Male	1.368	1.500	1.515	1.607	1.816	1.896	2.132	2.314	2.638	2.878	3.356
2003	1966	Male	1.848	1.691	1.653	1.909	2.126	2.295	2.465	2.644	2.976	3.150	3.471
1966	2003	Male	1.349	1.536	1.623	1.753	1.956	2.060	2.256	2.530	2.929	3.142	3.314
1966	1966	Male	1.730	2.358	2.003	2.242	2.472	2.576	2.623	2.758	3.278	3.664	4.208
2003	2003	Female	1.349	1.468	1.490	1.620	1.830	1.948	2.142	2.342	2.649	2.778	3.092
2003	1966	Female	1.681	1.710	1.745	1.922	2.128	2.236	2.438	2.685	3.088	3.336	3.561
1966	2003	Female	1.579	1.660	1.731	1.858	2.080	2.309	2.486	2.721	2.945	3.152	3.610
1966	1966	Female	1.783	2.012	2.242	2.272	2.420	2.542	2.738	3.047	3.357	3.848	4.383
Strain a	nd feed av	erage											
2003	2003	Ü	1.358	1.484	1.502	1.614	1.823	1.922	2.137	2.328	2.644	2.828	3.224
2003	1966		1.764	1.700	1.572	1.916	2.127	2.266	2.452	2.664	3.032	3.243	3.516
1966	2003		1.464	1.598	1.677	1.806	2.018	2.184	2.371	2.626	2.937	3.147	3.462
1966	1966		1.756	2.185	2.122	2.257	2.446	2.559	2.680	2.902	3.318	3.756	4.296
Pooled S	SEM		0.044	0.095	0.038	0.034	0.033	0.058	0.066	0.067	0.072	0.114	NA^3
Source of	of variation	n						<i>P</i> -value					
Strain			0.1325	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0003	0.0001	0.0009	NA
Diet			0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	NA
Sex			0.4392	0.0339	0.0008	0.1131	0.3510	0.2136	0.0932	0.1568	0.3008	0.4160	NA
Strain	× diet		0.0809	0.0001	0.0001	0.0053	0.0142	0.7066	0.9579	0.0526	0.9396	0.2655	NA
Strain	× sex		0.0009	0.1667	0.0165	0.2773	0.5516	0.1883	0.0670	0.4727	0.8936	0.7453	NA
$Sex \times c$			0.0157	0.1484	0.0322	0.4350	0.0577	0.0237	0.4281	0.4065	0.4332	0.1927	NA
Strain	× sex × die	et	0.8148	0.7356	0.8985	0.4527	0.0924	0.2996	0.6808	0.3400	0.8555	0.7386	NA

¹2003 = turkey dietary regimen representative of those being fed in calendar year 2003; 1966 = turkey dietary regimen representative of those being fed in 1966 (adapted from Ensminger, 1966). Both starter diets were fed as crumbles, and the 1966 grower diet was also fed as crumbles. All 2003 grower and finisher diets were fed as pellets. For the 1966 diet regimen, the starter was fed from 0 to 56 d, the grower from 57 to 112 d, and the finisher from 113 to 196 d of age. The 2003 regimen was fed as 7 different rations by 14-d periods from hatch to 98 d of age. A finisher diet was fed from 99 through 196 d of age.

Livability

Cumulative mortality rates by strain, age, sex, and diet group through 112 d of age are provided in Table 7. The mortality data from 112 to 196 d of age is not included, because 25% of the pens were killed to obtain processing data at 113 d of age, and another 25% were killed each 28-d period thereafter. None of the statistical comparisons were significant at any age period shown (Table 7), and overall livability to 112 d of age was very good for all groups. A few birds were culled during the course of the study and were included in the mortality due to the presence of leg problems or pendulous crops (data not shown), but there didn't appear to be any consistent pattern to the presence of these abnormalities by strain or diet.

Summary

Contribution of Genetics and Nutrition to Changes in Growth Rate. As was pointed out in the introduction, Sherwood (1977) and Havenstein et al. (1994a, 2003a) reported that about 85 to 90% of the change in broiler performance from 1957 until the years they conducted their comparisons were brought about due to the genetic selection practiced by commercial broiler breeding companies, and that the other 10 to 15% has come about from

changes in nutrition and nutritional management. One cannot reach such a clear conclusion from the data in this turkey study. The strains and sexes reacted very differently to the 2 dietary regimes over the course of the experiment. Table 3 summarizes the relative differences in response to the 2 dietary regimens. Both sexes of both strains performed much better on the 2003 diets from hatch to 4 to 6 wk of age than on the 1966 diets. Thereafter, with the exception of the modern hens, the birds on the 1966 diets began to perform better than those on the 2003 diets. After 9 to 10 wk of age (mid-May), it became very hot and humid and the birds on the 1966 diet, which contained higher protein and lower energy, started performing better than those on the higher energy and lower protein modern diets. It appears that the birds consuming the modern high-energy diets reduced their intake as an adaptive measure to minimize their heat stress, and, consequently, the reduced protein intake limited their growth. In contrast, the birds consuming the 1966 diet containing lower energy and higher protein were able to consume more feed during heat stress and therefore enough protein and other nutrients to support greater weight gain. This is not too surprising, because Veldkamp et al. (2002) recently reported that turkeys modulate feed intake when exposed to high ambient temperatures in relation to the caloric density of the diet. Follow-up studies need to be conducted to better understand how to

²2003 = composite of 5 birds each of Nicholas, British United Turkeys of America, and Hybrid turkeys; 1966 = RBC2 randombred control strain from The Ohio State University (Wooster).

³NA = not applicable; data from only 1 block of 8 pens available.

Table 7. Cumulative mortality of modern 2003 and 1966 randombred turkeys when fed representative 1966 and 2003 diets by strain, diet, sex and age

					Perce	entage of cu	ımulative m	ortality by	age (d)		
Item	Diet ¹	Sex	0 to 7	0 to 14	0 to 28	0 to 42	0 to 56	0 to 70	0 to 84	0 to 98	0 to 112
Strain ²											
2003	2003	Male	1.67	1.67	3.33	3.33	3.33	3.33	3.33	3.33	3.33
2003	1966	Male	1.67	1.67	1.67	1.67	1.67	5.00	5.00	5.00	5.00
1966	2003	Male	0.0	1.67	1.67	1.67	1.67	1.67	1.67	1.67	1.67
1966	1966	Male	1.67	3.33	3.33	6.67	6.67	6.67	6.67	6.67	10.00
2003	2003	Female	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.78
2003	1966	Female	0.0	0.0	0.0	0.0	1.67	1.67	1.67	1.67	3.33
1966	2003	Female	0.0	0.0	7.12	7.12	7.12	7.12	7.12	7.12	7.12
1966	1966	Female	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	3.56
Strain and feed avera	age										
2004	2003		0.84	0.84	1.67	1.67	1.67	1.67	1.67	1.67	5.05
2003	1966		0.84	0.84	0.84	0.84	1.67	3.33	3.33	3.33	4.15
1966	2003		0.00	0.84	4.40	4.40	4.40	4.40	4.40	4.40	4.00
1966	1966		1.72	2.55	2.55	4.25	4.25	4.25	4.25	4.25	6.78
Pooled SEM			0.46	0.68	0.72	0.72	0.76	0.80	0.80	0.80	0.89
Source of variation							<i>P</i> -value				
Strain			0.9866	0.1070	0.1622	0.0710	0.1480	0.3229	0.3229	0.3229	0.7488
Diet			0.3233	0.7771	0.6861	0.9594	0.7268	0.4593	0.4593	0.4593	0.5456
Sex			0.3396	0.7127	0.6282	0.3543	0.5574	0.3358	0.3358	0.3358	0.7801
Strain × diet			0.3233	0.7771	0.8964	0.7466	0.9947	0.6863	0.6863	0.6863	0.5337
Strain × sex			0.3233	0.3311	0.2929	0.5475	0.7845	0.5038	0.5038	0.5038	0.8853
Sex × diet			0.9866	0.3424	0.4454	0.2314	0.3957	0.2272	0.2272	0.2272	0.3047
Strain \times sex \times diet			0.9866	0.3424	0.3027	0.1458	0.0953	0.2272	0.2272	0.2272	0.3131

¹2003 = turkey dietary regimen representative of those being fed in calendar year 2003; 1966 = turkey dietary regimen representative of those being fed in 1966 (adapted from Ensminger, 1966). Both starter diets were fed as crumbles, and the 1966 grower diet was also fed as crumbles. All 2003 grower and finisher diets were fed as pellets. For the 1966 diet regimen, the starter was fed from 0 to 56 d, the grower from 57 to 112 d, and the finisher from 113 to 196 d of age. The 2003 regimen was fed as 7 different rations by 14-d periods from hatch to 98 d of age. A finisher diet was fed from 99 through 196 d of age.

²2003 = composite of 5 birds each of Nicholas, British United Turkeys of America, and Hybrid turkeys; 1966 = RBC2 randombred control strain from The Ohio State University (Wooster).

feed market turkeys under high ambient temperatures. Thus, from this study, the answer one would give as to whether nutrition and nutritional management has improved performance during the past 37 yr (i.e., from 1966 to 2003) is clearly dependent upon the age and the ambient temperature under which the measurement was taken.

In conclusion, the performance of modern market turkeys produced in 2003 was compared with that of randombred turkeys started in 1966, when grown using representative 1966 and 2003 diets. The data indicated that growth rate to market age has approximately doubled during this 37-yr period, and the BW of toms and hens have been increasing by approximately 208 and 140 g/ yr during this period. Feed efficiency was approximately 20% better in the 2003 tom turkey on the 2003 feed (2.638) than in the RBC2 tom on the 1966 feed (3.278) at 20 wk of age. Feed efficiency to 11 kg of BW in the 2003 toms (2.132 at 98 d of age) was approximately 50% better than in the RBC2 toms (4.208 at 196 d of age). The number of days to reach that weight was halved during this period. Livability was numerically better in the modern than in the randombred control line of turkeys, so the doubling of the growth rate, with its consequent reduction in FC in the modern turkeys, has not increased the mortality levels in modern turkeys to the ages studied.

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